Using the DRM false memory recall paradigm to investigate hemispheric asymmetry and sex differences.

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Abstract

The purpose of this study was to replicate that of Ito's (2001) in which hemispheric asymmetry was explored using a false recognition and list learning paradigm to induce high levels of false recall for semantically related, but non-studied, critical words. The experiment replicated that of Ito's in that it showed that the correct response rate for studied words and critical non-studied was significantly higher when the words were presented to the (rvf)-LH than when presented to the (lvf)-RH. As with Ito we discuss a model of fine semantic coding for the LH and coarse semantic coding to the RH to explain the results and asked whether the model was sufficient to explain this pattern of verbal memory recall. Furthermore, as increasing research has provided evidence that sex differences may provide a bearing upon verbal memory recall skills, we divided our 32 subjects evenly between both sexes. Although sex differences were not significant overall, which may be due to a low number of subjects tested, descriptive statistics showed that women generally had a higher correct recall of studied words, performing at a similar level to men in the LH but excelling in recall of studied words in the RH. However, women also falsely recalled the critical non-studied words in the RH more than men and this result did turn out to be significant. These results are also discussed under the coarse and fine coding model along with the idea that sex differences fall along a continuum related to the sex of an individual's brain rather than their outward biological gender.

Introduction

False memory recall research has developed considerably in recent years after the disturbing increase in 'repressed' memories amongst individuals who claim to have suffered childhood sexual abuse only to later find out that it never occurred. Loftus and Ketcham (1996) have explored these findings and discovered that not only do people regularly falsely recall events that never happened to them but, perhaps more disturbingly, they can be made to believe an event happened simply by being fed false information and directed by simple leading questions. Such work has drawn into question the reliability of certain witness testimonies as well as the more implausible evidence given by individuals who believe they have been abducted by aliens. Loftus' work caused The American Psychological Association to review repressed memory work, particularly in the case of individuals recalling 'repressed memories' of sexual abuse and concluded that most people who suffered such incidents remembered all or part of what had happened to them but that it was extremely rare for them to completely forget such events and later recover them. However, it did state: "Concerning the issue of a recovered versus a pseudomemory, like many questions in science, the final answer is yet to be known" (Spinney, 2003).

A growing amount of research, such as the work of Daniel Wright and colleagues at Sussex University, studies what makes people more susceptible to false memory recall. Another side of the research question investigates from a cognitive neuroscience approach exactly how these false memories come into being and which areas of the brain are involved in the complex memory process. For example, Anderson and Green (2001) found that if individuals deliberately tried to suppress a word they found it harder to recall the word at a later stage. Using fMRI imaging they examined what happened when individuals undertook this suppression of memory and discovered a dampening of activity around the hippocampus, a structure critical for memory formation, but also concurrently a higher activation in the frontal cortex. They suggested that the frontal cortex activation was a result of the neurons in this region actively suppressing the representation of the word in the hippocampus.

This current research is a replication and extension of Ito's (2001) who examined hemispheric asymmetry in the induction of false memories. Ito used a false recognition paradigm and a standard list learning paradigm in order to investigate hemispheric asymmetry in verbal memory recall. Ito discovered, for Japanese, that the left hemisphere could discriminate the targets from related distractors more accurately than the right hemisphere, the latter being more likely to falsely recall words which had not been previously presented during the list learning phase. In contrast our research examines whether such a theory would hold true for English words and also investigates sex differences in false memory recall.

One argument against the validity of such research as Ito's, and Anderson and Green's, in the investigation of suppressed false memory recall is that in contrast to recovering childhood memories subjects are being asked to recover words they saw only moments before. Furthermore, Anderson himself admitted that his work ignores the effect of a memory's emotional intensity (Spinney, 2003). Subsequent work by Richardson et al. (2003) investigated this phenomenon and found subjects were more likely to remember an emotionally arousing word such as *murder* or *scream* than a more neutral one, such as *carpet* or *block*. However, a counter argument is that this type of research is not intended to replicate that of Loftus, rather it is an investigation of the cognitive styles that lie behind the creation of the false memories themselves. Furthermore, Loftus herself was able to induce false memories in only matter of minutes with her subjects and often these memories were of childhood experiences that never happened, for example, seeing Bugs Bunny at Disneyland (Spinney, 2003).

The DRM List Learning and False Recognition Paradigm

Similar to Ito (2001) we will be using the list learning and false recognition paradigm. In 1959 Deese discovered that when presented with a list of words to recall later, subjects could be induced to falsely remember a non-presented critical word. For example, if the critical word was *needle*, the list of associated words presented to the subject would be *thread, pin, eye, sewing, sharp, point, pricked, thimble, haystack, pain, hurt* and *injection*. Deese wanted to know why some lists gave rise to this effect whilst others did not, and he concluded that lists which generated a priming association between words both forwards and backwards were most likely to elicit false recall.

To elaborate on this we can begin with the semantic priming paradigm which argues that if a subject is shown a *prime* such as 'feline' this will activate in their memory related concepts so that when they are subsequently shown the *target* word 'cat' they will respond faster. If the prime speeds up the process of identification we call this *facilitation*, but if it slows down identification we call this *inhibition* (Harley, 2001). One way to increase facilitation of the target is by using summation priming, or in Deese's case by presenting subjects with lists of semantically associated words. Anderson's (1983) spreading activation theory argues that items which are closely related will be close together in a cognitive network. Activate one of these items and the activation will spread through the whole network. However, only some primes will work both forwards and backwards, for example, *pine* might prime *needle,* but *needle* does not facilitate the priming of *pine.* Deese (1959) found his most successful word lists were ones where priming of associatives worked both ways.

Roediger and McDermott (1995) decided to replicate Deese's work using six critical words from Deese's original article: *chair, mountain, needle, rough, sleep* and *sweet*. They created their corresponding lists of 12 associates by using Russell and Jenkins (1954) word association norms. During the learning phase subjects heard the lists of words and subsequently wrote them down on successive pages of an exercise book. In the recognition phase of the experiment Roediger and McDermott constructed a list of 12 studied and 30 non-studied words. The 30 non-studied words, or lures, consisted of the following:

a) The 6 critical words from which each list was generated;

b) 12 words generally related to any items on the six lists;

c) 12 words weakly related to the lists (2 per list) drawn from position 13 or below in the association norms.

During the recognition phase participants were asked whether each word had appeared on the original lists or not, and also rated their confidence for each word as to whether they *remembered* or *knew* the word had been on the original list.

Roediger and McDermott (1995) found high levels of false recall in both this experiment and a subsequent one using more extensive materials (24 words lists of 15 words). Furthermore, they found that when subjects were questioned about this false recall they would respond quite positively as having 'known' that the word was on the original list. Perhaps even more surprising was that in subsequent work McDermott and Roediger (1998) found that even if subjects were instructed to pay careful attention as to whether or not the critical word had been presented in the original lists, they still demonstrated the false recall phenomenon, although the effect was reduced by the warning, this effect was also found by Neuschatz et al. (2003).

This list learning paradigm, often referred to by other researches as the DRM (Deese, Roediger and McDermott) paradigm has subsequently been used in other experiments to explore, amongst other things, converging associative networks (Watson, Balota and Roediger, 2003); memory illusions, (Roediger, 1996); long lived semantic priming (McKone and Murphy, 2000); and even memory distortion in individuals who claim to have been abducted by aliens (Clancy, et al., 2002). Clancy et al. (2002) discovered that individuals who reported recovery and repressed memories of alien abduction were more susceptible than control participants to exhibit false recall and recognition in a DRM paradigm. Clancy et al. (2002) argue that the DRM paradigm acts as a type of source monitoring error, in other words remembering how, why and where a memory is acquired. They argue that a child watching a movie about aliens could, in later years, believe this actually occurred as a result of forgetting where the original memory was acquired.

Further research has shown that robust false recognition occurs when people rely on their memory for the general semantic features of studied items (Schacter et al., 1998). Subjects tie the studied items together forming a focused representation of the semantic features so that during the recall phase related non-studied distractors elicit high false recall, but unrelated distractors are quickly rejected.

Ito (2001) expanded the DRM paradigm in order to investigate hemispheric asymmetry by using Hamajima's (2000) Japanese word lists and presenting the words during the recall phase to both the left and right visual fields in order to examine the processing differences between the hemispheres. With regards to replicating Ito's work some problems do arise. For example, it is not possible to replicate the work in English using Hamajima's word lists which consist of the following

14 critical words: *drinking, money, apple, pleasant, rest, warm, reading, black, television, foot, desk, buying, hope* and *music*. This is simply because although the word for *reading* may spawn a large list of semantic associatives in Japanese, in English this is not quite as obvious as using the word *read*.

Furthermore, even with the Roediger and McDermott studies, associative norms have usually been taken from collections such as Postman and Keppel (1970) which apart from being out of date have the added drawback for this author in that they were collected from American college students during the 1950s and 1960s and are unlikely to be relevant to British English speakers in the twenty first century. For this reason we have chosen to use the *Birbeck Word Association Norms* by Moss and Older (1996).

We were unable to determine whether previous researchers studying false memory recall have ever used pre testing when constructing their word lists. This would seem to be an important control given that the language used by young adults is usually full of different idioms compared to that of older individuals. Since it is from within the 17 to 30 year-old age group that the majority of subjects will come from, it is from within this age group that the author pre-tested the materials to be used in the word association lists by using a simple questionnaire asking subjects to list 10 to 15 words they would associate with the given critical word. Nearly all the critical words have been taken from Roediger and McDermott's original experiment, with the exception of one, *galaxy,* which replaced *girl* in the original list in order to avoid duplication of words during the list learning phase. The words are: *anger, black, bread, chair, cold, doctor, foot, fruit, galaxy, high, king, man, mountain, music, needle, river, rough, sleep, slow, soft, spider, sweet, thief* and *window* (see Appendix for full word lists used).

Beeman and Bowdens' coarse and fine coding theory in hemispheric asymmetry

It has long been acknowledged that for right handed individuals the left hemisphere is usually dominant for language production and comprehension. However, such a model can appear as an 'all-or-nothing' scenario, ignoring the role of the right hemisphere in language processing. For example, the right hemisphere has a role in processing ambiguous word meanings (Burgess & Simpson, 1988) and some individuals exhibit weaker language lateralization which means their language skills are spared after a unilateral lesion (Knecht et al., 2002). Furthermore, there is growing evidence that the sex of the individual may also play a role in language lateralization. This will be discussed later.

Ito (2001) wanted to examine whether the coarse and fine coding model (Beeman, 1998) of the hemispheres would hold for verbal memory when using the false memory induction paradigm. In 1998 Beeman proposed a model of semantic processing in which the left hemisphere (LH) engages in fine semantic coding, strongly focusing activation on a single interpretation of a word and a few closely related associates, whereas the right hemisphere (RH) engages in coarse semantic coding, weakly activating several meanings and associates (see Figure 1). Another way of describ-

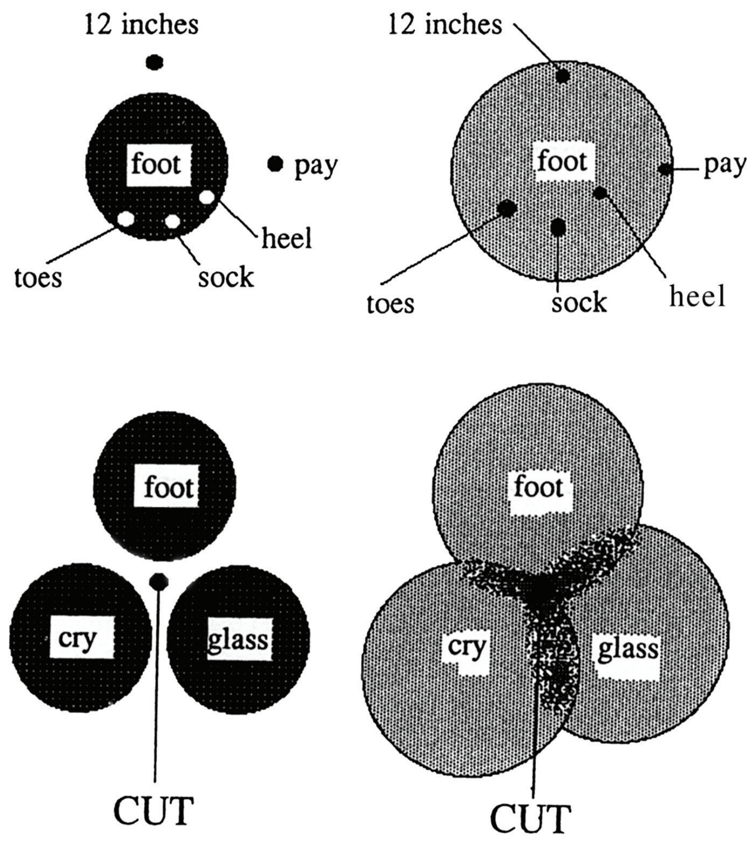

Figure 1. Taken from Beeman et al. (1994)Top: The left hemisphere strongly activates a small semantic field, whereas the right hemisphere weakly activates a large semantic field. Bottom: The right hemisphere's large semantic fields from distantly related words are more likely to overlap. Weak activation from multiple sources summates where the semantic fields overlap, activating an inferred concept that can connect the distantly related words.

ing this is by saying that whereas the right hemisphere sees the woods, the left can discriminate between the individual trees. Furthermore, Beeman et al. (1994) in support of this model found greater priming effects for certain prime types when target words were presented to the left-visual field (lvf)-RH than when presented to the right-visual field (rvf)-LH, in particular the phenomenon was greater when the target word was distantly related to the preceding prime.

Working from this premise Ito (2001) made the following predictions: first, that the hit rate for studied words would be higher when the targets were presented to the (rvf)-LH than the (lvf)-RH since presentation of strongly related targets at encoding should activate the target more strongly in the LH, since this hemisphere encodes in strongly activated but small semantic fields. In our tree analogy the LH will see the tree and remember specifically what type of tree it is. In contrast the RH with its weaker but broader semantic fields will activate all the trees in the forest but with a lesser degree of accuracy in determining which tree was originally presented. With this in mind Ito made a second prediction; false recognition would be high in both hemispheres on presentation of the critical word, but specifically the RH would show higher false recall as unlike the LH it lacks the fine tuning to separate semantically similar items.

Ito's (2001) results supported the hypothesis, the RH did indeed show higher levels of false recall, but not as strongly as hoped. There may be some methodological problems and theoretical issues which could account for the results. First, Ito did not pre test the word lists, as discussed earlier. Some of the subjects may not have found the critical word to be as strongly associated with the target words, a problem which we discuss below. Secondly, there are some anomalies with Ito's procedure. During the list learning phase each participant sees 14 lists of 14 words each list consisting of words closely associated to the critical word. Each trial begins with the subject fixating on a central cross before the word presentation began on the centre of the screen. Each word on the list appears for 1.5 s and at the end of each list the participant carries out a distractor task (solving a maths problem) before moving on to the next list.

The problem arises during the recognition phase. On presentation of the critical words, related and non-related distractors, participants are asked to press *yes* or *no* as to whether the word appeared on the original list. What makes Ito's procedure troubling is that each word during the recall phase was presented once to the (rvf)-LH, and then once again to the (lvf)-RH, meaning each participant saw the critical word twice. This should have *increased* the false recognition effect since the critical word could very easily prime itself across visual fields, and as a result Ito should have seen more significant results. Ito does not explain why the double presentation procedure of each word during the recall phase was thought to be necessary, since randomising the words and counterbalancing the stimuli across the participants would be enough to control for presentation to the visual fields.

Beeman et al (1994) may provide an answer to Ito's less than robust results. They note: "By definition, the large semantic fields activated by RH coarse semantic coding are only weakly activated, and weak facilitation of the target word might be difficult to detect - just as weak RH semantic processing of single words is difficult to observe" (Beeman et al., 1994, p.29). They went on to point out that "deficits in discourse processing in RHD patients are relatively easy to observe, perhaps because such processing relies heavily on semantic overlap from multiple distantly related words" (*Ibid.*) This in turn implies that in normal individuals such deficits are much harder to determine. Furthermore, given that during the recall phase subjects only see the words presented to either the (lvf)-RH or (rvf)-LH for 120 ms in order to prevent the eyes moving away from the fixation point, it gives the brain relatively little cognition time to process the semantic relations of one word before moving on to the next. Therefore, this author expects that although the results will show a similar hit and miss rate pattern to that of Ito's, there will be a smaller degree of difference between the hemispheres for false recognition because the critical words will only be presented once either to the (lvf)-RH or (rvf)-LH. This does not disparage Beeman's (1993) coarse and fine coding theory in any way. On the contrary, the fact that any difference can be found between the hemispheres during such a rapid presentation of words is remarkable in itself given the difficulty of observing semantic processing of single words.

Furthermore, the materials used in the word lists are important with regards as to how individuals create semantic relationships. Watson, Balota and Roediger (2003) explored the idea of over-additive false memories being produced by converging associative networks. For example, word lists that had both phonological and semantic relations produced higher false recall effects than lists created from just pure semantic relationships or phonological relationships. It would seem logical that increasing the overlap between words via semantics and phonetics will cause the coarse coding of the RH to illicit higher false recall during the recognition phase for critical non-studied words. This drew further importance to pre testing such materials before carrying out the trials.

An interesting point to note about the pre testing is it elicited some unusual results. It became apparent during the pre testing phase that what individuals see as being semantically related to given words can diverge quite dramatically. For example, one participant for the word *anger*, listed *management* and *hate* in the first two positions of the list. Another listed *mad* and *red*. It is important, therefore, to note that no matter how well constructed the materials used in the word lists, they can never reflect every individual's preferences for what they consider to be the most important semantic relations within their own lexicon. In an experiment which attempts to look at the semantic processing of individual words, a task already noted as difficult by Beeman et al. (1994), it becomes even clearer that even the best materials can never overcome individual differences with respect to semantic relations, and therefore may help explain Ito's results and also further emphasises the remarkableness of finding any differences between hemispheres to begin with.

Sex differences

"It turns out that male and female brains differ quite a bit in architecture and activity". So begins Larry Cahill's article in Scientific American which explores recent findings into the structural, chemical and functional variations between the male and female brains (Cahill, 2005). The interest in sex differences in the brain has only begun to develop in recent years. Previous to this it was 'ideologically fashionable to insist these behaviour differences are minimal and are the consequences of variations in experience during development before and after adolescence" (Kimura, 1992). Part of this was as a result of a feminist backlash against Victorian research that claimed that since the female brain was smaller than a man's, women were intellectually inferior. Unfortunately, such research failed to acknowledge that in proportion to the overall body size there was no differences in brain size, but the thinking held for some time with some of the more extreme scientists of the day claiming intelligent women were such an anomaly they must be mad and placed in an asylum (BBC: Secrets of the Sexes, 2005). The reticence to re-open the brain sex difference case book has perpetuated until this day, but modern research has begun to draw up biological lines of differences between male and female brains that reflect on the similarities in overall intellect but generated across different cognitive functions such as language or spatial awareness.

One field of investigation is language. For some time sociolinguists and anthropologists have noted that males and females socially employ language in quite different ways, often as a response to the gender stereotyping and positioning of the societies they belong to (Holmes & Meyerhoff, 2003). Perhaps because of its origins in sociolinguistics sex differences in verbal performance have almost been completely ignored by psycholinguists who often cite the socially gendered aspect of such observations, and inconsistent neurological findings as a reason for this omission (Harley, 2001). However, recent developments in imaging techniques of the brain and new research methods are resulting in mounting evidence for sex differences not only at the structural level, but right down to the cellular level of the brain (Cahill, 2005). Yet the social differences observed between the sexes in language use may have a biological basis according to the sex of the brain. For example, Shaywitz et al. (1995) confirmed the theory that language is less lateralized in female brains and may also be processed differently with female brains showing a far greater degree of activation in the right hemisphere than that of males. Furthermore, this is displayed in the audio medium. When played two different words into speaker headphones, a technique called dichotic listening, Harshman et al. (1983) found that men reported only one word, that spoken into the left ear. In contrast women could report hearing two distinctive words, one from each ear. A social example of this ability might be explored in Coates (1994) work which studied the turn-taking mechanisms used by female friends in conversations. Coates found that women rarely have pauses in their conversation, but can easily overlap each others' sentences. This ability for an individual to overlap in what both a speaker is hearing and saying whilst still carrying out a fluid conversation could be regarded as a social demonstration of an underlying biological difference.

In 1996 Voyer carried out an extensive meta-analysis of research into sex differences. He concluded that "laterality effects are significant and relatively consistent. Specifically, the largest laterality effects are found in verbal tasks in the visual and auditory modality." Since this study is carried out within the visual modality it seems relevant to mention this phenomenon in the present study.

Voyer is careful to note that where laterality is concerned caution needs to be exercised before attempting to use the findings for theory elaboration (Voyer, 1996). However, one explanation for the inconsistency between some of the findings may be that sex differences can be seen as an all-or-nothing scenario. An individual is either male or female, with no possibility of an individual expressing traits of the opposite sex. Yet in the real world this is simply not true on either a biological level (for example, hermaphrodites) or on a social level (not all women are born housewives, not all men want to be merchant bankers). Perhaps a better paradigm would be to view the sex of the brain as falling along a continuum that is not necessarily related to the biological gender of the individual. Some men can exhibit female brain characteristics and vice versa.

One important theory that can aid this paradigm is Baron-Cohen et al.'s (2001) which argues that autism and Asperger's Syndrome (AS) lie on a continuum of social-communication disability, with AS acting as a bridge between normality and autism. Carrying out a number of tests using the Baron-Cohen Autism Quotient scale they found significant differences between the sexes. Males scored significantly higher than females, both overall and at intermediate and high levels of autistic traits.

Developing this idea further Baron-Cohen (1999) put forward the hypothesis that autism is an example of the extreme male-brain. This began with his observation that a significantly higher proportion of males than females suffer from either autism or Asperger's Syndrome, a relationship that had previously received little research attention. Baron-Cohen drew on various findings including the fact that in general, females show a faster rate of language development and a lower risk for specific language impairment (Hyde & Linn, 1988; Bishop, 1990). This may be as a result of females having less lateralization in the brain for language compared to males. Baron-Cohen argues that one important assumption of his model is that people fall on a continuum as regards male or female brain types and this can be attributed to the amount of testosterone and androgens a foetus is exposed to at conception through to full gestation in the uterus.

A general area that has been accepted as a sex difference is that of verbal memory recall. Whereas men usually outperform women on visuo-spatial tasks, women outperform men in verbal memory recall and fluency (Kimura, 1992; see also Lewin et al., 2001; Herlitz et al., 1997 and 1999). Kimura (1992) also discusses the influence of sex hormones on the foetus during development. She notes that administering androgens just after birth will affect the sexual behaviour of an individual. However, this appears to only be effective at a critical stage of development: administering the androgens a later stages in an adult's life has no effect on the sexual behaviour. However, on a BBC programme, *Secrets of the Sexes,* the producers had the rare opportunity to study someone undergoing a sex change with the use of testosterone. They wanted to see how the process of an individual changing from a woman to a man with the aid of testosterone therapy would affect brain function in a typically female area: emotional response. The argument behind this was that testosterone should not be able to alter the function of an adult brain as it had developed past the critical sensitivity stage. However, contrary to this hypothesis the individual did manifest direct changes in the brain. Before the administration of testosterone the subject's brain performed like a female's in response to emotional stimuli when visualized using fMRI. After administering testosterone the individual performed almost exactly like a man, with no response to emotional stimuli that is usually seen in the female brain. This surprising result helps the Baron-Cohen (1999) hypothesis that it is indeed the male hormones a person is exposed to that will determine specific cognitive abilities in the brain.

How can we apply these ideas to the current work? If female brains are indeed less lateralized then we can hypothesise that there will be a greater degree of false memory recall when critical words are presented to a female's right hemisphere. The reason for this is that the coarse coding of the right hemisphere in females is likely to be far more active for verbal tasks than in males, so distantly related (but non-studied) words are more likely to be drawn up as targets than in the male brain. Furthermore, we can also hypothesise that the hit rates for studied words will be higher in females than males, given this ability to retain larger semantic fields in the right hemisphere. It may also be that females will be better than males in disregarding non-related distractors. Because the left hemisphere fine coding in both sexes is no different, we will expect the results in this hemisphere for all types of distractor to be equal. If sex differences do not exist then we would expect the false recall rates and correct hit rates for alll types of distractor words to be equivalent in both males and females.

In relation to Baron-Cohen's work we would also expect to find the results falling along a continuum. For this reason we have also included the Autism Quotient questionnaire in the experiment. A copy of the questionnaire can be found in the appendix.

EXPERIMENT

Methods

Participants. 32 subjects between the ages of 18 and 30 were selected to include 16 females and 16 males. All were native speakers of English and were found to be dominant right-handers using the Edinburgh Handedness Inventory (Oldfield, 1971). All had normal or corrected-to-normal vision. All subjects were paid £6 for participating in the experiment.

Materials and apparatus. Twenty four word lists were used, each consisting of 16 words to include the critical non-studied word and fifteen studied words. For example, for the critical non-studied word *galaxy*, the associated word list were *stars, universe, planet, bar, space, cosmos, infinite, Milky-Way, black hole, nebula, constellation, satellite, moon, sun, asteroid*. The full word list can be found in the appendix. The word lists were selected from the original Roediger and McDermott (1995) experiment, with one exception; *galaxy* replaced *girl* in order to avoid word replication during the recall phase. The word lists were also pre-tested before the experiment among a group of similar aged individuals who did not take part in the experiment. They were also checked against the Moss and Older (1996), *Birbeck Word Association Norms*.

Design. Visual field and type of distractor word (i.e. studied, critical or non-studied) were the two variables manipulated in the experiment. Both VF (lvf, rvf) and distractor were varied within subject. Gender was included as a between subject variable. Response accuracy was the dependent measure.

Procedure. The experiment fell into two phases. The first was the list learning phase which began with a central fixation cross followed by the word presented horizontally in the centre of the screen. Each word was presented for 1.5 s. In contrast to Ito, who arranged the within-list order according to the strength of association to the critical word, each word list was presented randomly and was counterbalanced across subjects. After the subject had seen all 15 words of a particular list they solved maths problems as a distractor task for 30 seconds before moving on to the next list. This pattern was repeated until each subject had seen all 24 words lists. Again, the order of list presentation was counterbalanced across subjects.

After the final word list had been studied the subjects filled out the Autism Quotient and Edinburgh Handedness scale before moving on to the recall phase. Instructions for the recall phase were presented on the screen with subjects being told to press keys on a response box for *yes* or *no* in response to the question, had the word been on any of the original lists? The *yes* or *no* keys on the response boxes were also counterbalanced across subjects. The trial began with a central fixation point followed by a word presented either to the left or right of the fixation point, horizontally for a duration of 120 ms to prevent re-fixation. The subject gave their answer via the response box before the next word was presented. The recall phase consisted of 96 items: 48 studied words, 24 unrelated distractors and the 24 critical words (see Appendix for word lists). Order of presentation was random and counterbalanced across subjects with each subject seeing 50% of the words to the right visual field, and 50% to the left visual field. The unrelated distractors were selected to be as unassociatively related to the word lists as possible and were pre tested by individuals who did not take part in the experiment.

In contrast to Ito (2001), who presented each word once to the left and then the right visual field, we presented each word only once to either the right or left visual field. It was felt that Ito's

(2001) method of presenting each word twice would artificially increase the false response rate of the critical word since each critical word could prime itself across the visual fields. In contrast to Ito (2001), rather than using a chin rest restraint subjects were explicitly instructed to remain as still as possible during the recall phase and remain fixated on the central cross during the trials. They were told to respond as accurately as possible.

Subjects were sat in soundproofed booths in front of Dell Optiplex GX1 machines with Pentium III 733MHz processors and Intel i810e integrated graphics adaptors with 8Meg VRam, displaying at 1024x768 @ 16bit colour @ 60Hz to an Iiyama TXA3823 15” analogue LCD screens. The experiment was run on eStudio software.

Results

Full results for each subject can be found in the appendix. We calculated the mean correct response rate and false alarm rate for each subject in each condition. As with Ito we presented the hit rates and false alarm rates as a function of the visual field (see Figure 2.). We then analysed these in separate repeated ANOVAs. A one way ANOVA for VF indicated that the hit rate was significantly higher when the words were presented to the (rvf)-LH than when presented to the (lvf)-RH, $F(1,31) = 3.314$, $p < .05$. We then carried out a 2 (VF) x 2 (type of word) ANOVA. A significant

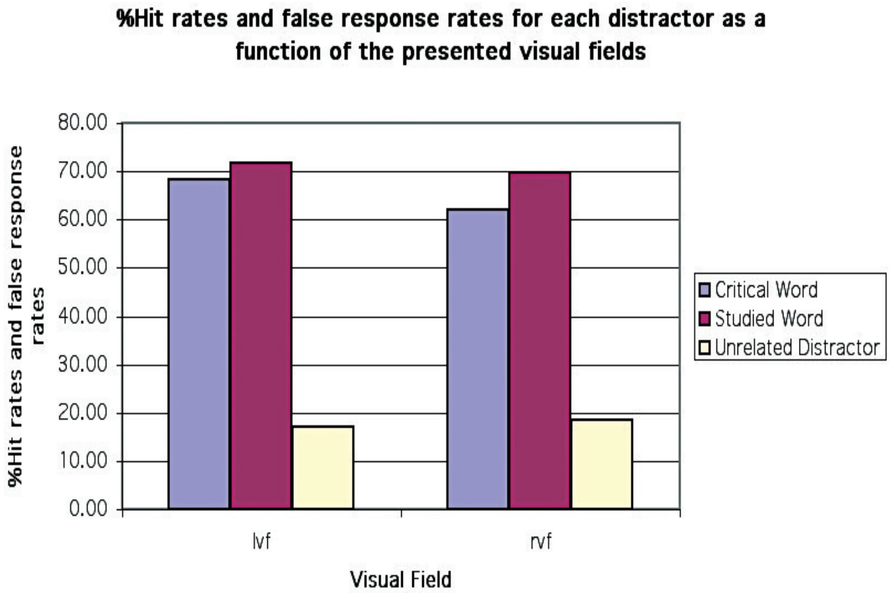

Figure 2. Hit rates for studied words and critical words, and false alram rates for non-stuided critical words as a function of the visual fields.

main effect for type of distractor was found, F(1,31) = 174.051, $p < .001$. The false alarm rate was significantly higher for the critical, non-studied words than for the unrelated non-studied distractors. A significant effect of visual field was also found, F(1,31) = 4.703, $p < .04$. As with Ito's work we found that the false alarm rate was significantly higher when words were presented to the (lvf)-RH than in the (rvf)-LH. The VF x type of distractor interaction was not significant, F(1,31) = .224, $p > .5$. All these results replicated those of Ito's (2001).

We also ran a repeated ANOVA on the interaction between hemisphere and gender. Gender was not significant overall, F(1, 31) = 10.941, p = .072. However, separate repeated ANOVAs were run to determine the interaction between gender and type of words. A significant effect of gender was found for correct responses for critical, non-studied words, F(1,30) = 4.610, $p < .05$. In general males correctly rejected the critical non-studied words more than females as was suggested by the descriptive statistics (see Figure 3). Furthermore, females had a higher false alarm rate when critical words were presented to the (lvf)-RH (M=73.4%) than when presented to the left (M=62.5%).

Ito (2001) also analysed hemispheric differences by looking at their ability to discriminate between critical words and non-studied

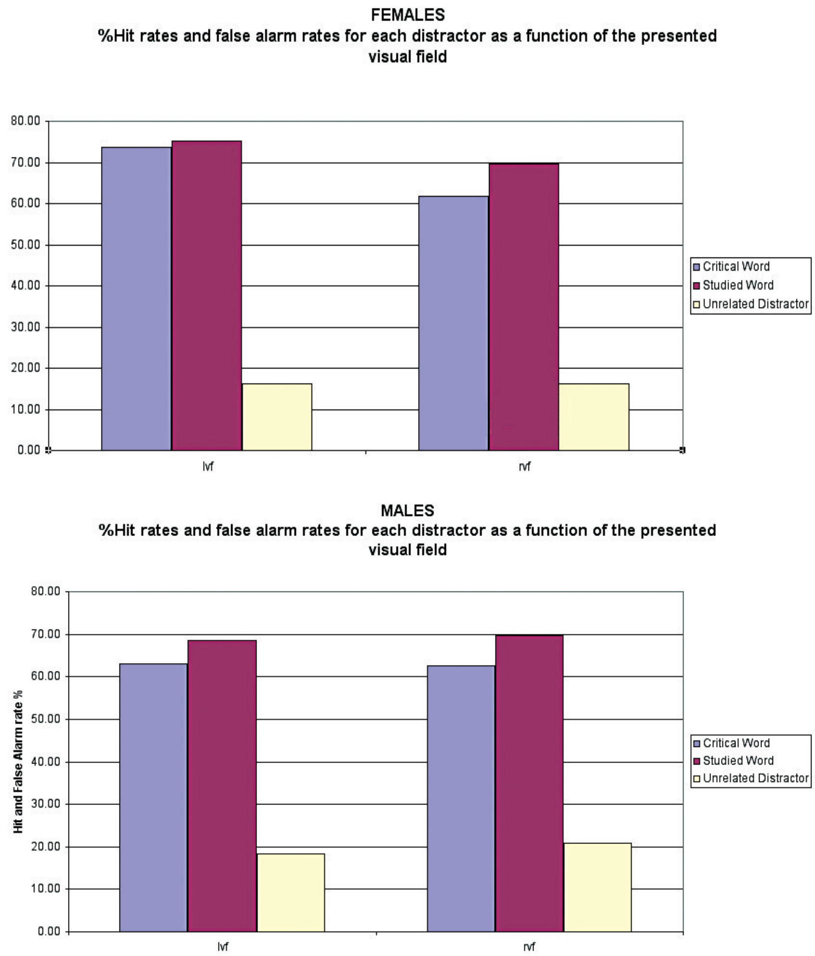

Figure 3. Plots comparing the hit and false alarm rates for males and females.

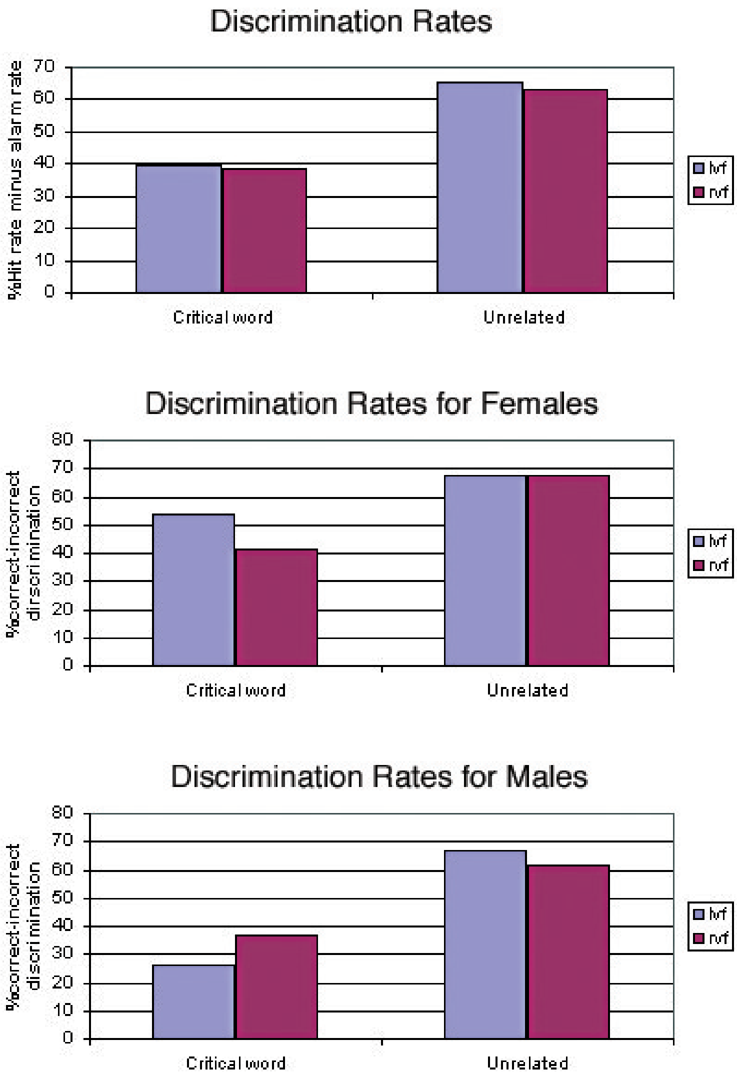

Figure 4. Discrimination scores (correct response minus incorrect response) for critical words and non-related distractors.

words. We repeated this analysis in the same way as Ito by calculating the discrimination scores, that is the correct response minus the incorrect response for critical words and unrelated non-studied words. Furthermore, since we were also interested in sex differences we separated these results for males and females, see Figure 4, in order to see if a further pattern of results emerged related to sex differences.

Unlike Ito (2001) a one way ANOVA did not indicate that the discrimination score was significantly higher when stimuli were presented in the (rvf)-LH than the (lvf)-RH, $F(1,31) = .186$, $p > .5$. This is probably due to a difference in our methodology by only presenting each word once to either the left or right visual field. A between ANOVA analysis indicated that gender was a factor; $F(1,30) = 5.962$, $p < .05$; but was not a significant interaction for the pattern of results found. Although the descriptive results for males was similar to that of Ito's (2001), in that for males the LH seemed better able to discriminate between the critical words and non-studied distractors. Furthermore, the descriptive results for the discrimination scores show that females again have a higher false alarm rate in the (lvf)-RH for critical words than compared with males. As a final analysis we also ran a between subject ANOVA to investigate the Autism Quotient scores, but the results were non-significant and as yet no pattern of results has emerged from these findings. Again this may be due to the small number of subjects. However, as predicted the subjects results did fall along a continuum with some male subjects displaying low AQ, usually associated with more female results and vice versa. These results can be found in the Appendix and are discussed below.

Discussion

The results replicated Ito's (2001) work in that we found the correct response rate was significantly higher when words were presented to the (rvf)-LH than to the (lvf)-RH. The false recall rate of the critical non-studied words was also higher than that of the non-related distractors, regardless of which visual field they were presented to. Although we did not find a significant difference in the ability of the LH to more accurately discriminate studied words from critical non-studied words than the RH this result was probably due to our change in Ito's (2001) methodology. Ito presented each word to both visual fields increasing the likelihood of self-priming. Therefore, having once seen the critical word the brain is more likely to reject or accept the word as having been on the original lists according to its order of presentation during the recall phase. This could have a direct bearing on the hemispheres ability to discriminate between critical words and non-related distractors. Furthermore, our use of equal numbers of male and female subjects may have a bearing on these results.

Although we did not find an overall effect of gender there were some significant results with regard to the type of distractor words. In general, males correctly rejected the critical non-studied words more than females. Furthermore, females had a higher incorrect response rate when critical words were presented to the (lvf)-RH than when presented to the left. Although this result was not significant, $F(1,31) = 3.974$, $p = .055$, it was borderline to be of interest for our current research considering the correct response rate for gender was significant, $F(1,30) = 4.610$, $p < .05$. Gender was thought not to be significant overall as a result of the lack of degrees of freedom, although this can only be confirmed by repeating the experiment with larger numbers of subjects for both sexes in the future.

The pattern of correct and false response fits well with Beeman's (1998) coarse and fine coding theory. For both males and females the RH falsely recalled the critical word higher than the LH, demonstrating the coarse semantic coding of the right hemisphere; and the LH conversely rejected the critical words more than the RH, demonstrating the fine semantic coding and thereby the more selective nature of the left hemisphere in verbal memory recall. What is of interest is the difference between the two sexes. Why should females falsely recall in the RH more than males? Again the Beeman (1998) model can help us here.

If the female brain is indeed less lateralized than the male with regards to language skills then it would seem appropriate to suggest that in females the right hemisphere is more active during the encoding process compared to males, and thereby creates larger semantic networks of related words. If this is the case then we hypothesised that during the recall phase the right hemisphere in females will show an advantage for correct response to studied words in the RH over the males, which we discovered in our descriptive statistics. For studied words the correct response in the (lvf)-RH for females was M= 75.26%, and for males it was M= 68.49%. However, our hypothesis also argued that a disadvantage would be found in females compared to males when responding to the critical word in the (lvf)-RH. Again we found this in our descriptive statistics where females M=26.04%, and males

M=36.98%. This result turned out to be significant, $F(1,30) = 4.610$, $p < .05$. The correct and incorrect response results for the (rvf)-LH in both sexes were almost identical regardless of type of distractor. This suggests that the observed difference in results for the (lvf)-RH is therefore due to a processing difference in the right hemisphere of females compared to males. This would also help explain the results for the discrimination scores. Although the results for males were similar to that of Ito's (2001), in that the left hemisphere could discriminate between critical words and non-studied words better than the right hemisphere, the results for females did not show this discrimination. It could be hypothesised, therefore, that in females the advantage in the RH for correct responses to studied proves a disadvantage for critical and non-studied words. In particular, if the RH in females is more engaged at the onset for encoding words into a far broader semantic network compared to males, it may explain why females falsely recall even the unrelated distractor words as having been on the original lists more frequently than males. It would seem to completely rule out this anomaly it is very important for the recall phase to include a list of unrelated distractor words that can have absolutely no associative or semantic link to any of the original studied items or critical words.

These results fit well with current theories regarding hemispheric differences between the sexes (Voyer, 1996). Another aspect is how the sexes differ in their response to encoding memories. For example, Cahill (2005) and his colleagues found contrasts in the way men and women respond to emotional memories. They began their experiments by drawing on animal research investigating the activation of the amygdala. This is a section of the brain that forms part of the limbic node, a collection of structures, including the hypothalamus, that is thought to be a system for emotional behaviour and memory. The amygdala is a bundle of neurons anterior to the hippocampus involved in explicit and implicit emotional memory learning (Gazzangia et al., 2002). Cahill showed his subjects clips of graphically violent films whilst measuring their brain activity using PET. The subjects were then quizzed a few weeks later to see what they had remembered. They found that the number of films remembered was related to the activation of their amygdala during the viewing. Cahill then noticed something unusual in this pattern of activation; some of his experiments resulted in activation of only the right side of the amygdala, and some only to the left. Those involving right side activation only were found to be from male subjects, and those involving left side activation of the amygdala involved only female subjects.

To test the hypothesis Cahill returned to the idea "that the right hemisphere is biased toward processing the central aspects of a situation, whereas the left hemisphere tends to process the finer details" (Cahill, 2005). In many respects a theory not dissimilar to Beeman's (1998) coarse and fine coding paradigm. Cahill decided to use a drug called propranolol which dampens the activity of the amygdala. If his theory was correct then this dampening effect would hamper a man's ability to recall the gist of the story, and women's ability to remember the details. His results supported the theory.

This brings back to mind the work of Richardson et al. (2003) who found their subjects were more likely to remember an emotionally arousing word such as *murder* or *scream* than a more neutral one, such as *carpet* or *block*. However, Richardson et al. (2003) did not include sex differences as part of their paradigm, and this may be one area of interest to investigate for future work along with an investigation on the influence of the amygdala on verbal memory creation and recall.

Further cognitive neuroscience research has begun to explore the neural patterns of memory distortion. Schacter and Slotnick (2004) recently completed an overview of current research into false recognition using both ERP and fMRI imaging work and found the results, “converged on the conclusion that there is a neural sensory signature that can distinguish between true and false recognition, and that neuroimaging and neuropsychology evidence converge on the conclusions that regions within the medial temporal lobe are related to the generation of false recognition, whereas regions within prefrontal cortex are related to memory monitoring activities” (Schacter and Slotnick, 2004). In terms of sex differences this remains an area largely unexplored but if Cahill’s (2005) work on the amygdala is an indicator of sex differences then it would be reasonable to assume further imaging research would also find activation differences between the sexes in these areas associated with false memory recognition.

Re-defining ‘sex differences’: is it really *his* brain, *her* brain, or is a better definition *male* brain, *female* brain?

Voyer (1996) notes in his meta-analysis that in investigating hemispheric differences between the sexes some studies find differences whilst others do not. Voyer suggests the following:

> “A partial answer to this question may reside in the fact that many studies involve samples of participants that are too small to allow detection of sex differences. One can only wonder why such low sample sizes are used when the effects under study are so small. It is quite likely that, because most researchers are not interested primarily in the detection of sex differences, they use a sample size sufficient for the main effect of laterality to reach significance. Given that the magnitude of laterality effects is much larger than that of sex differences in laterality, this results in studies that are powerful enough to

> detect laterality effects but not sex differences. From this perspective it might prove useful for future researchers to present power calculations for sex differences in laterality and to include the sample size required for this effect to be significant when it fails to reach conventional significance."
>
> (Voyer, 1996, p.70)

In defence of this current research to Voyer's criticism, we were bound by both time and financial limits, but we do agree with Voyer that far larger subject numbers are required when studying sex differences. Furthermore, as we were attempting to replicate Ito's (2001) work it was felt best at the time to use the same number of subjects as Ito did, since we were primarily interested in whether this paradigm could be replicated. With the best will in the world 16 subjects of each sex was not going to give us enough data points to find significant sex differences. The fact that some were found, however, does indicate that further research needs to be carried out in this area. Therefore, one of the first goals of the author's further work will be to carry out the same experiment but on a much larger population sample. There are, however further considerations with regards to sex differences that need to be accommodated.

Currently in selecting participants for experiments investigating sex differences, researchers rely on the outward biological appearance of the individual to segregate individuals into male and female categories. However, as we have seen earlier a male can present with female brain aspects and vice versa. Returning to the Baron-Cohen studies we expected to see sex differences fall along a continuum. This can be seen by examining the Autism Quotient data from our results (see Appendix), for example male subject number 108 had an AQ score of 7, and female subject number 102 had an AQ of 27. Baron-Cohen et al. (2001) carried out a comparison of Autism Quotients for individuals with Asperger Syndrome/high-functioning autism, control males and females, and scientists and mathematics. The average score for normal individuals was AQ = 16.4 (males AQ = 17.8 and females AQ = 15.4). The difference between sexes was found to be significant and no female scored above 34 on the AQ whereas 4% of males did. Furthermore, Baron-Cohen et al. (2001) found that twice as many males (40%) compared to females (21%) scored at the intermediate level, that is an Autism Quotient score of 20 or more. From our two subjects above we could describe them as falling into the AQ category more suitable to the opposite sex on the AQ continuum.

Furthermore, although Baron-Cohen (2001) and his colleagues also tested students they did not find a significant deviation in Autism Quotient scores compared to the control group with one exception: students of sciences (this includes mathematics) who all scored significantly higher on the AQ compared to students of humanities and social sciences. Baron-Cohen et al. (2001) also had a fourth group of Cambridge Mathematics Olympiad winners who scored an average of 24.5 on the AQ (15 males and 1 female). This confirmed Baron-Cohen et al.'s earlier study that autistic conditions are associated with scientific skills, and may also help explain why fewer women than men study subjects such as mathematics.

Lawrence Summers, President of Harvard University, sparked an international furore in February 2005 by suggesting that brain biology explained why fewer women than men succeed in the sciences (Cahill, 2005). The problem with Summers' comment is that it was taken out of context, after all Summers did not say *all* women fail in sciences only that fewer women succeed compared to men. His comments also did not include the fact that women succeed more than men in other fields of academia and the results either way bear no relation to general intelligence. As we have seen from Baron-Cohen's work a better description might have been to say those individuals with a high Autism Quotient score are more likely to succeed in sciences than those with a lower score. Such a description eliminates the gender argument and its associated ideologies. After all, in the sample of Mathematics Olympiad winners although 15 were male and only one was female, yet they all scored above average on the AQ.

If outward gender is not a reliable factor for sex differences we can use the Autism Quotient in future experiments to pre test individuals and categorise them according to their brain sex. But the AQ score alone is not enough. As Baron-Cohen et al. (2001) note, "The AQ is thus a valuable instrument for rapidly quantifying where any given individual is situated on the continuum from autism to normality", but it is not reliable at this stage to situate an individual's brain on the continuum from male to female.

Another scale that could be used comes from Manning's work on 2nd and 4th finger ratio. The ratio between these two fingers has long been accepted as a sexually dimorphic trait. In general, the mean 2D:4D ratio in men is lower than that in women (Phelps, 1952). This anomaly was in later years found to be under the control of the Homeobox, or *Hox* genes, which also control the differentiation of testes and ovaries during development of the foetus (Peichel et al., 1997; Herault et al., 1997). Manning et al. (1998) took this idea one step further and suggested that patterns of 2D:4D ratios may reflect aspects of gonadal function such as the production of testosterone and oestrogen.

During gestation, the human foetus is exposed to testosterone and oestrogen at different stages of its development. Obviously, high testosterone will favour a male foetus, and high oestrogen the female foetus (Manning et al., 2000). Manning et al. (2000) argued that the 2nd to 4th finger ratio is also a marker for sexually antagonistic genes that exert their effects prenatally:

> "On the one hand, low 2D:4D may indicate prenatal exposure to high testosterone and low estrogen levels, a situation that enhances fertility in males but reduces it in females. On the other hand, high 2D:4D ratios may correlate prenatally with low testosterone and high estrogen and be associated with low fertility in males and high in females."
>
> (Manning et al., 2000, pp.164-165)

But how would this influence the development of the brain?

> "The prenatal period, particularly, the first trimester of pregnancy, is very important for the organization of the central nervous system, urinogenital system, and cardiovascular system. Prenatal testosterone and estrogen have their impact on differentiation when systems show sex-limited differences. Therefore, it is likely that 2D:4D will prove to be a marker for many traits that show sex limited expression. These may include behavioral traits such as handedness, verbal fluency, spatial judgment, autism, schizophrenia, and depression."
>
> (*Ibid*, p.181)

One such area is language, so we could hypothesise that if the brain during foetal development is also influenced by these hormone fluctuations, regardless of the biological sex of the individual, the brain sex will be also reflected in 2D:4D ratio, and like the Autism Quotient it also reflects the nature of brain sex to fall along a continuum.

Until recently it was thought that testosterone would not have an effect on the brain's performance once an individual had developed past a certain point. But as we mentioned in the introduction, on the BBC programmes *Secrets of the Sexes*, Sunday July 17th, producers had a unique opportunity to follow one individual undergoing a sex change from a woman to a man. Over the course of four years the individual underwent testosterone hormone therapy. Before this began she was examined for emotional response using fMRI imaging techniques. Her performance was typically female, in that during a session of being shown faces and asked to determine what expression each was showing, a central part of the brain became highly active, a phenomenon not seen in male brains. However, after four years of testosterone therapy, he returned to have the same procedure done. Amazingly, and much to the surprise of the researcher, he no longer exhibited female activation during the emotional response test. The point of this is, if added testosterone can affect emotional performance even as an adult, it could also have a bearing on future linguistic performance during foetal development explaining why the female brain is less lateralized. Therefore we would expect that 2D:4D ratio to be a good predictor of brain sex and hence performance in false memory recall experiments and verbal memory performance in general.

It may seem rather far fetched to use finger ratio as a predictor for this sort of behavioural traits but the paradigm does seem to be rather robust. For example, Manning carried out an experiment for *Secrets of the Sexes* (BBC, 17th July, 2005) in which he predicted the outcome of a running race between six men by using their 2D:4D ratios. Manning argued that 2D:4D ratios were an indicator of the development of cardiovascular systems during foetal development. Men with low

2D:4D would therefore be better athletes. The six individuals were measured for their 2D:4D ratios and Manning attached a hidden number, predicting their finishing position, to each one. At the end of the race the numbers were revealed. One individual in particular had a very low 2D:4D and this was the eventual winner of the race. All the other positions were also correct except for position 3 and 4. Both these men had very similar 2D:4D ratios and also finished very close together in the race. As Manning commented the results were surprising even to him, given that before the day of the race he had not met any of the men and there could have been other factors involved, such as fitness on the day or any recent injuries that could also have influenced the outcome of the race.

As Manning et al. (2000) also point out, 2D:4D ratios do overlap considerably in males and females suggesting sex limited expression is not complete. Part of this is attributed to natural evolution, but it also highlights the idea that individual sex differences should be seen as occurring along a continuum with males able to express female brain characteristics and females able to express male characteristics.

An interesting inclusion among Manning et al.'s (2000) list is handedness. In our results, on average, males scored slightly higher on the Edinburgh Handedness scale than females; males EH = 9.63, females EH = 9.5. This could also be a reflection of the lower degree of lateralization in the female brain and could, therefore, be used in conjunction with Autism Quotient and 2D:4D ration to predetermine the sex of an individuals brain before an experiment.

Taking hemispheric asymmetry investigation one step further

Despite some quite rigorous alterations to Ito's original work we still managed to replicate most of the results. Ito (2001) presented words during the recall phase to both the left and right visual fields. We decided not to follow this method as there was concern that the critical non-studied words could prime themselves across visual fields and thereby give us artificially high false recall rates. Furthermore, the sets of word lists and number of items in the recall phase for this experiment more closely resembled that of Roediger and McDermott (1995). This meant that our subjects had larger word lists during the learning phase and therefore a much harder task when negotiating the items during the recall phase. Yet despite these added hurdles our results were remarkably similar to Ito's, demonstrating the robustness of the experimental procedure, as well as the durability of false memory recall and the DRM paradigm in general.

Since this paradigm is robust for investigating hemispheric asymmetry, one area of research that could be explored is whether or not Beeman's (1998) coarse and fine coding will hold true for dominant left handers. Current thinking suggests that in dominant right handers language function is predominantly situated in the left hemisphere. The reverse may be true for dominant left handers. However, we need to be cautious in investigating this area as not all research shows that brain function is a reversed in left handers. However, one interesting piece of research that may be relevant to our investigation of coarse and fine coding theory is that of Mevorach et al. (2005).

Mevorach et al. (2005) were investigating global and local information processing in the brain, a theory similar to Beeman's coarse and fine coding theory. This assumes that the right hemisphere is better at attending to the global aspects of a hierarchical object (the forest), whereas the left is better at attending to the local aspects (the trees). They used Transcranial Magnetic Stimulation (TMS); a technique in which transient disruption of normal brain activity can be induced by applying a focal magnetic pulse to specific regions of the scalp thereby simulating the effects of a lesion; to examine the role of the right and left posterior parietal lobes. They found that "opposite, homologous regions in the two hemispheres are involved in attending to local parts for left- and right-handed individuals. The brain regions that focus on the 'trees' while ignoring the 'forest' are switched as a function of handedness" (Mevorach et al., 2005). In other words in right-handed individuals the left posterior parietal can focus on local form while ignoring the global information, but in left-handers the right posterior parietal lobe carries out this function.

Theoretically, if we were to carry out our experiment using dominant left-handers we could hypothesise that our pattern of results for the hemisphere would be reversed. That is, the right hemisphere in left-handers would be dominant for language and attending to fine coding, and therefore better at rejecting the critical words during the recall phase compared to the right hemisphere.

Conclusion

The main outcome of our work was that we managed to replicate Ito's (2001) results, although not the discrimination scores. However, since we altered the methodology this may have influenced this particular result. Furthermore, as laterality effects can be quite small and hard to investigate it may be, as with investigating sex differences, that our results simply are a reflection of too small a population sample. In addition to this, as sex differences may have an influence on the outcome of false memory recall, since we used an even ratio of male to female subjects whereas Ito (2001) had only 4 males out of 32 subjects, this may also have been a factor in our failure to find significant discrimination scores.

Although sex differences were not significant overall some aspects of type of distractor were found to be significant, in particular the result of females falsely recalling the critical word more than males. Again, Voyer's (1996) criticism of research into sex differences needs to be accommodated with again attention being paid the number of participants used. Furthermore as Beeman et al. (1994) noted since weak right hemisphere semantic processing of single words is difficult to observe when we add this to the factor of sex differences being difficulty to observe along with laterality effects it becomes even more surprising that any results of significance were found, and provides a good testimony for the Robustness of Beeman's (1998) coarse and fine coding model as well as Ito's (2001) experimental paradigm for investigating hemispheric asymmetry.

Such findings could play an important role in how we model language performance. Traditionally, psycholinguists have preferred to fit one model to both sexes, but if language function is different between the sexes than this one-model-fits-all approach may not always be appropriate, particularly in experiments which rely on any form of verbal memory recall, such as investigating garden-path sentences or anaphora resolution (Harley, 2001). It may be that the sometimes conflicting results observed by psycholinguists in these experiments is a factor of sex distribution in subjects rather than a factor of experimental procedure per se.

Outcomes and Further Work

One immediate outcome of this work is that in replicating Ito's (2001) work we have put forward an abridged version of this thesis to be published in the journal, *Laterality* (see Appendix). Furthermore, several avenues of research have developed from this experiment.

The first is an investigation into hemispheric asymmetry using dominant left handers to determine whether coarse and fine coding patterns in the hemispheres is completely reversed compared to that of dominant right handers. That is, will left handers show fine coding in the right hemisphere and coarse coding in the right hemisphere in a similar manner to the reverse patterns Mevorach et al. (2005) found in using TMS to investigate attention to local and global forms.

The second is a more thorough investigation into sex differences in false memory recall that the author hopes will develop into a more formal PhD proposal. One idea that has developed specifically, is to see whether Manning et al.'s (2000) suggestion that 2D:4D ratio can be used as a marker, in this case to investigate false memory recall by categorising individuals not by their outward biological sex, but by their brain sex. To do this we propose an experiment in which subjects are pre tested for brain sex before undertaking the false memory recall experiment. Along with 2D:4D finger ratio it is proposed we also use the Autism Quotient and handedness to define our subjects into male and female brain categories. A simple way of doing this is to specifically recruit individuals, as Baron-Cohen et al. (2001) did from areas of academia where we would expect to find more males than females, for example mathematics and science subjects, and more females than males, for example humanities and art subjects.

In investigating the cognitive neuroscience aspect of false memory recall another avenue of approach would be examining the brain during false recall to see where the memories are encoded and to investigate the patterns of brain activity between males and females, or to be more specific under this theory, male and female brains. Another area of interest to the author is Alzheimer patients and their development of illusionary memories.

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Appendix

Word Association Lists

Fruit	Anger	Black	Bread	Chair	Cold	Doctor	Foot
apple	rage	white	butter	table	hot	nurse	shoe
basket	fear	dark	jam	legs	ice	hospital	ball
tree	hate	cat	board	stool	winter	ill	mouth
juice	fury	blue	sandwich	seat	wet	injection	toe
pear	red	funeral	flour	back	freeze	health	ankle
ripe	temper	colour	milk	desk	snow	stethoscope	sock
salad	violence	grief	yeast	wood	frozen	patient	sole
banana	wrath	green	dough	sofa	chilly	prescription	walk
strawberry	fight	death	crust	cushion	heat	pills	smell
orange	chaos	ink	roll	sitting	weather	treatment	boot
dessert	hatred	bottom	slice	swivel	fridge	office	run
vegetables	mean	coal	wine	furniture	air	medical	sore
bowl	emotion	brown	loaf	arm	shiver	surgeon	step
cocktail	shouting	raven	toast	rocking	Arctic	clinic	odour
berry	enrage	grey	bap	bench	frost	cure	hand

River	Galaxy	High	King	Man	Mountain	Music	Needle
water	stars	low	queen	woman	hill	note	thread
stream	universe	sky	royal	boy	steep	sound	pin
lake	planet	tall	ruler	uncle	climb	pop	eye
wide	bar	tower	prince	person	summit	score	sewing
boat	space	airplane	crown	wife	top	sheet	sharp
tide	cosmos	altitude	England	male	molehill	stave	point
swim	infinite	flying	palace	father	peak	song	prick
flow	Milky-Way	kite	throne	strong	plain	book	thimble
runs	black hole	rise	chess	friend	glacier	stereo	haystack
barge	nebula	far	sovereign	beard	goat	singing	thorn
creek	constellation	vertigo	subjects	being	bike	guitar	hurt
brook	satellite	hopes	monarch	handsome	climber	record	sting
fish	moon	giant	castle	muscle	range	piano	stitch
bridge	sun	lofty	leader	suit	valley	tune	cloth
winding	asteroid	mighty	reign	old	ski	orchestra	knitting

Window	Rough	Sleep	Slow	Soft	Spider	Sweet	Thief
pane	smooth	dreams	fast	hard	web	sour	steal
glass	ready	bed	down	warm	insect	sugar	robber
ledge	ground	night	quick	comfort	fly	tooth	crook
sill	tough	pillow	snail	feathers	arachnid	chocolate	burglar
curtain	sandpaper	awake	stop	cosy	crawl	good	money
frame	stubble	peace	coach	cuddly	tarantula	taste	police
house	surface	rest	delay	gentle	poison	sticky	bad
open	coarse	slumber	traffic	touch	bite	nice	law
broken	uneven	doze	tortoise	fluffy	creepy	honey	jail
closed	justice	tired	hesitant	furry	animal	syrup	criminal
view	rugged	snore	speed	downy	ugly	toffee	villain
breeze	cut	nap	bus	kitten	feelers	heart	crime
sash	bark	nightmares	sluggish	skin	small	cake	bank
soul	rocky	yawn	wait	tender	nasty	wrapper	dishonest
shutter	gravel	drowsy	idle	snug	eerie	pie	pillage

Recall Phase

Studied Words

apple	rage	white	butter	table	hot	nurse	shoe
basket	fear	dark	jam	legs	ice	hospital	ball
water	stars	low	queen	woman	hill	note	thread
stream	universe	sky	royal	boy	steep	sound	pin
pane	smooth	dreams	fast	hard	web	sour	steal
glass	ready	bed	down	warm	insect	sugar	robber

Critical Words

fruit	anger	black	bread	chair	cold	doctor	foot
river	galaxy	high	king	man	mountain	music	needle
window	rough	sleep	slow	soft	spider	sweet	thief

NonStudied Words

judge	cathedral	truth	enzyme	boomerang	station	exile	walrus
gift	skeleton	Orient	clown	saucepan	helicopter	diamond	computer
rake	cravat	canvas	address	pulley	briefcase	broom	university

The AQ

TO BE COMPLETED BY PARTICIPANT

ALL INFORMATION REMAINS STRICTLY CONFIDENTIAL

Name:.. Sex:..

Date of birth:.................................. Today's Date................................

How to fill out the questionnaire

Below are a list of statements. Please read each statement very carefully and rate how strongly you agree or disagree with it by circling your answer.

DO NOT MISS ANY STATEMENT OUT.

Examples

E1. I am willing to take risks.	definitely agree	slightly agree	slightly disagree	definitely disagree
E2. I like playing board games.	definitely agree	slightly agree	slightly disagree	definitely disagree
E3. I find learning to play musical instruments easy.	definitely agree	slightly agree	slightly disagree	definitely disagree
E4. I am fascinated by other cultures.	definitely agree	slightly agree	slightly disagree	definitely disagree

1. I prefer to do things with others rather than on my own.	definitely agree	slightly agree	slightly disagree	definitely disagree
2. I prefer to do things the same way over and over again.	definitely agree	slightly agree	slightly disagree	definitely disagree
3. If I try to imagine something, I find it very easy to create a picture in my mind.	definitely agree	slightly agree	slightly disagree	definitely disagree
4. I frequently get so strongly absorbed in one thing that I lose sight of other things.	definitely agree	slightly agree	slightly disagree	definitely disagree
5. I often notice small sounds when others do not.	definitely agree	slightly agree	slightly disagree	definitely disagree
6. I usually notice car number plates or similar strings of information.	definitely agree	slightly agree	slightly disagree	definitely disagree
7. Other people frequently tell me that what I've said is impolite, even though I think it is polite.	definitely agree	slightly agree	slightly disagree	definitely disagree
8. When I'm reading a story, I can easily imagine what the characters might look like.	definitely agree	slightly agree	slightly disagree	definitely disagree

9. I am fascinated by dates.	definitely agree	slightly agree	slightly disagree	definitely disagree
10. In a social group, I can easily keep track of several different people's conversations.	definitely agree	slightly agree	slightly disagree	definitely disagree
11. I find social situations easy.	definitely agree	slightly agree	slightly disagree	definitely disagree
12. I tend to notice details that others do not.	definitely agree	slightly agree	slightly disagree	definitely disagree
13. I would rather go to a library than a party.	definitely agree	slightly agree	slightly disagree	definitely disagree
14. I find making up stories easy.	definitely agree	slightly agree	slightly disagree	definitely disagree
15. I find myself drawn more strongly to people than to things.	definitely agree	slightly agree	slightly disagree	definitely disagree
16. I tend to have very strong interests which I get upset about if I can't pursue.	definitely agree	slightly agree	slightly disagree	definitely disagree
17. I enjoy social chit-chat.	definitely agree	slightly agree	slightly disagree	definitely disagree
18. When I talk, it isn't always easy for others to get a word in edgeways.	definitely agree	slightly agree	slightly disagree	definitely disagree
19. I am fascinated by numbers.	definitely agree	slightly agree	slightly disagree	definitely disagree
20. When I'm reading a story, I find it difficult to work out the characters' intentions.	definitely agree	slightly agree	slightly disagree	definitely disagree
21. I don't particularly enjoy reading fiction.	definitely agree	slightly agree	slightly disagree	definitely disagree
22. I find it hard to make new friends.	definitely agree	slightly agree	slightly disagree	definitely disagree
23. I notice patterns in things all the time.	definitely agree	slightly agree	slightly disagree	definitely disagree
24. I would rather go to the theatre than a museum.	definitely agree	slightly agree	slightly disagree	definitely disagree
25. It does not upset me if my daily routine is disturbed.	definitely agree	slightly agree	slightly disagree	definitely disagree
26. I frequently find that I don't know how to keep a conversation going.	definitely agree	slightly agree	slightly disagree	definitely disagree
27. I find it easy to "read between the lines" when someone is talking to me.	definitely agree	slightly agree	slightly disagree	definitely disagree
28. I usually concentrate more on the whole picture, rather than the small details.	definitely agree	slightly agree	slightly disagree	definitely disagree
29. I am not very good at remembering phone numbers.	definitely agree	slightly agree	slightly disagree	definitely disagree
30. I don't usually notice small changes in a situation, or a person's appearance.	definitely agree	slightly agree	slightly disagree	definitely disagree
31. I know how to tell if someone listening to me is getting bored.	definitely agree	slightly agree	slightly disagree	definitely disagree
32. I find it easy to do more than one thing at once.	definitely agree	slightly agree	slightly disagree	definitely disagree
33. When I talk on the phone, I'm not sure when it's my turn to speak.	definitely agree	slightly agree	slightly disagree	definitely disagree
34. I enjoy doing things spontaneously.	definitely agree	slightly agree	slightly disagree	definitely disagree

35. I am often the last to understand the point of a joke.	definitely agree	slightly agree	slightly disagree	definitely disagree
36. I find it easy to work out what someone is thinking or feeling just by looking at their face.	definitely agree	slightly agree	slightly disagree	definitely disagree
37. If there is an interruption, I can switch back to what I was doing very quickly.	definitely agree	slightly agree	slightly disagree	definitely disagree
38. I am good at social chit-chat.	definitely agree	slightly agree	slightly disagree	definitely disagree
39. People often tell me that I keep going on and on about the same thing.	definitely agree	slightly agree	slightly disagree	definitely disagree
40. When I was young, I used to enjoy playing games involving pretending with other children.	definitely agree	slightly agree	slightly disagree	definitely disagree
41. I like to collect information about categories of things (e.g. types of car, types of bird, types of train, types of plant, etc.).	definitely agree	slightly agree	slightly disagree	definitely disagree
42. I find it difficult to imagine what it would be like to be someone else.	definitely agree	slightly agree	slightly disagree	definitely disagree
43. I like to plan any activities I participate in carefully.	definitely agree	slightly agree	slightly disagree	definitely disagree
44. I enjoy social occasions.	definitely agree	slightly agree	slightly disagree	definitely disagree
45. I find it difficult to work out people's intentions.	definitely agree	slightly agree	slightly disagree	definitely disagree
46. New situations make me anxious.	definitely agree	slightly agree	slightly disagree	definitely disagree
47. I enjoy meeting new people.	definitely agree	slightly agree	slightly disagree	definitely disagree
48. I am a good diplomat.	definitely agree	slightly agree	slightly disagree	definitely disagree
49. I am not very good at remembering people's date of birth.	definitely agree	slightly agree	slightly disagree	definitely disagree
50. I find it very easy to play games with children that involve pretending.	definitely agree	slightly agree	slightly disagree	definitely disagree

Scoring the AQ

'Definitely agree' or 'slightly agree' responses scored 1 point, on the following items: 2, 4, 5, 6, 7, 9, 12, 13, 16, 18, 19, 20, 21, 22, 23, 26, 33, 35, 39, 41, 42, 43, 45, 46.

'Definitely disagree' or 'slightly disagree' responses scored 1 point, on the following items: 1, 3, 8, 10, 11, 14, 15, 17, 24, 25, 27, 28, 29, 30, 31, 32, 34, 36,37, 38, 40, 44, 47, 48, 49, 50.

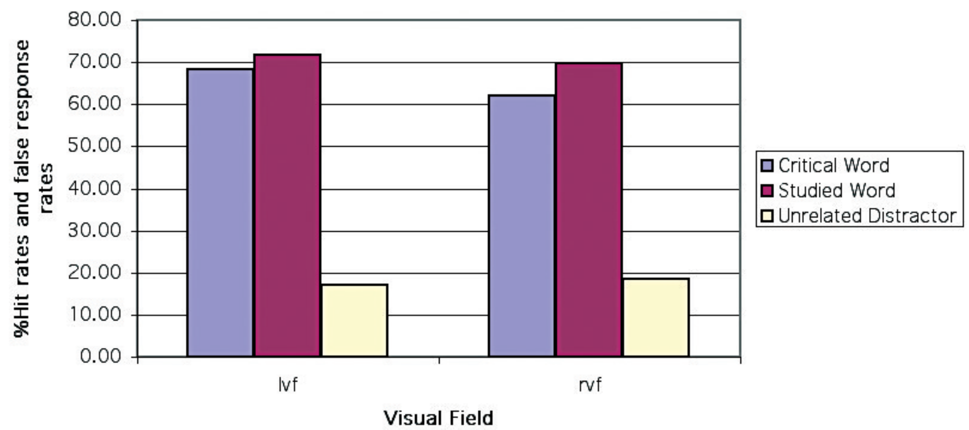
Overall Results

				Left Visual Field						Right Visual Field						EPI Results			
				Critical Words		Studied Words		Non Studied Words		Critical Words		Studied Words		Nonstudied words					
Subject	EHS	Age	Gender	%Correct	%Incorrect	%Correct	%Incorrect	%Correct	%Incorrect	%Correct	%Incorrect	%Correct	%Incorrect	%Correct	%Incorrect	Extrovers	Neurotic	Lie/Fib	AQ
101	10	25	m	25.00	75.00	83.33	16.66	75.00	25.00	16.66	83.33	75.00	25.00	83.33	16.66	7	21	1	27
104	10	24	m	33.33	66.66	62.50	37.50	100.00	0.00	25.00	75.00	87.50	6.25	91.66	8.33	14	6	3	15
105	9	23	m	8.33	91.66	87.5	12.5	83.33	16.66	8.33	91.66	70.83	29.16	50	50	9	14	3	25
108	9.5	23	m	41.66	58.33	75	25	66.66	33.33	50	50	79.16	20.83	75	25	17	13	3	7
109	10	21	m	33.33	66.66	83.33	16.66	83.33	16.66	16.66	83.33	75	25	100	0	14	7	0	18
112	9.5	28	m	50	50	60	40	83.33	16.66	16.66	83.33	65.22	34.78	100	0	16	11	4	18
113	10	25	m	33.33	66.66	62.5	37.5	100	0	58.33	41.66	66.66	33.33	91.66	8.33	7	4	2	22
116	9.5	22	m	41.66	58.33	58.33	41.66	75	25	41.66	58.33	41.66	58.33	83.33	16.66	16	14	2	15
117	8	23	m	41.66	58.33	56.57	43.48	91.66	8.33	41.66	58.33	48	52	75	25	15	9	4	28
120	9.5	25	m	41.66	58.33	62.5	37.5	83.33	16.66	58.33	41.66	54.16	45.83	75	25	15	8	3	16
121	10	23	m	50	50	43.48	56.52	75	25	41.66	58.33	72	28	75	25	7	9	1	14
124	10	18	m	41.66	58.33	58.33	41.66	83.33	16.66	41.66	58.33	45.83	54.16	83.33	16.66	8	5	4	20
125	9	22	m	33.33	66.66	70.83	29.16	66.66	33.33	41.66	58.33	87.5	12.5	66.66	33.33	17	8	3	13
128	9.5	19	m	41.66	58.33	87.5	12.5	100	0	16.66	83.33	87.5	12.5	83.33	16.66	6	12	2	18
129	10	22	m	41.66	58.33	79.16	20.83	83.33	16.66	58.33	41.66	87.5	12.5	83.33	16.66	9	17	4	24
132	9.5	19	m	33.33	66.66	66.66	33.33	58.33	41.66	66.66	33.33	70.83	29.16	50	50	1	13	5	37
102	8.5	28	f	25.00	75.00	33.33	66.66	50.00	50.00	41.66	58.33	45.83	54.16	91.66	8.33	7	11	5	27
103	8	27	f	46.15	53.85	82.61	17.39	41.66	58.33	9.09	90.09	68.00	32.00	91.66	8.33	13	17	1	16
106	10	21	f	25	75	79.16	20.83	91.66	8.33	16.66	83.33	79.16	20.83	83.33	16.66	10	10	5	9
107	9.5	22	f	25.00	75.00	76.00	24.00	100.00	0.00	41.66	58.33	86.96	13.04	91.66	8.33	6	12	3	17
110	10	21	f	8.33	91.66	72.00	28.00	75.00	25.00	33.33	66.66	56.52	43.48	58.33	41.66	13	12	4	7
111	10	26	f	16.66	83.33	91.66	8.33	91.66	8.33	41.66	58.33	79.16	20.83	75	25	11	5	2	9
114	9	20	f	16.66	83.33	70.83	29.16	66.66	33.33	58.33	41.66	37.5	62.5	66.66	33.33	16	12	1	13
115	10	19	f	75	25	91.66	8.33	100	0	58.33	41.66	95.83	4.16	100	0	17	6	1	9
118	10	21	f	50	50	70.83	29.16	83.33	16.66	100	0	87.5	12.5	91.66	8.33	6	10	1	16
119	9.5	21	f	25	75	91.66	8.33	91.66	8.33	50	50	66.66	33.33	83.33	16.66	14	15	0	12
122	9	20	f	25	75	79.16	20.83	100	0	25	75	66.66	33.33	91.66	8.33	12	0	3	19
123	10	23	f	8.33	91.66	79.16	20.83	91.66	8.33	33.33	66.66	75	25	91.66	8.33	10	15	3	14
126	9.5	22	f	25	75	70.83	29.16	83.33	16.66	50	50	41.66	58.33	91.66	8.33	17	10	0	8
127	9.5	18	f	0	100	75	25	66.66	16.66	0	100	75	25	75	25	12	12	5	10
130	9.5	26	f	25	75	66.66	33.33	91.66	8.33	25	75	70.83	29.16	75	25	11	18	3	16
131	10	25	f	25	75	70.83	29.16	100	0	25	75	83.33	16.66	83.33	16.66	12	8	1	10
Mean	9.53	22.56		31.65	68.35	71.84	28.16	82.29	17.18	37.78	62.19	69.69	30.11	81.51	18.49				
SD	0.57	2.76		15.34	15.34	13.50	13.50	15.23	14.96	20.81	20.78	15.89	16.15	13.00	13.00				

Results

	Critcial M% Incorrect%	Studied M% Correct%	NonStudied Word M% Incorrect%
lvf	68.35	71.84	17.18
rvf	62.19	69.69	18.49

%Hit rates and false response rates for each distractor as a function of the presented visual fields



Using the DRM false memory recall paradigm to investigate hemispheric asymmetry and sex differences.

Abstract

The purpose of this study was to replicate that of Ito's (2001) in which hemispheric asymmetry was explored using a false recognition and list learning paradigm to induce high levels of false recall for semantically related, but non-studied, critical words. The experiment replicated that of Ito's in that it showed that the correct response rate for studied words and critical non-studied was significantly higher when the words were presented to the (rvf)-LH than when presented to the (lvf)-RH As with Ito we discuss a model of fine semantic coding for the LH and coarse semantic coding to the RH to explain the results and asked whether the model was sufficient to explain this pattern of verbal memory recall. Furthermore, as increasing research has provided evidence that sex differences may provide a bearing upon verbal memory recall skills, we divided our 32 subjects evenly between both sexes. Although sex differences were not significant overall, which may be due to a low number of subjects tested, descriptive statistics showed that women generally had a higher correct recall of studied words, performing at a similar level to men in the LH but excelling in recall of studied words in the RH. However, women also falsely recalled the critical non-studied words in the RH more than men and this result did turn out to be significant. These results are also discussed under the coarse and fine coding model along with the idea that sex differences fall along a continuum related to the sex of an individual's brain rather than their outward biological gender.

Introduction

This current research is a replication and extension of Ito's (2001) who examined hemispheric asymmetry in the induction of false memories. Ito used a false recognition paradigm and a standard list learning paradigm in order to investigate hemispheric asymmetry in verbal memory recall. Ito discovered, for Japanese, that the left hemisphere could discriminate the targets from related distractors more accurately than the right hemisphere, the latter being more likely to falsely recall words which had not been previously presented during the list learning phase. In contrast our research examines whether such a theory would hold true for English words and also investigates sex differences in false memory recall.

Similar to Ito (2001) we will be using the Deese (1959), Roediger an McDermott (1995) list learning and false recognition paradigm. Ito (2001) expanded the DRM paradigm in order to investigate hemispheric asymmetry by using Hamajima's (2000) Japanese word lists and presenting the words during the recall phase to both the left and right visual fields in order to examine the processing differences between the hemispheres. With regards to replicating Ito's work some problems do arise for our research. For example, it is not possible to replicate the work in English using Hamajima's word lists which consist of the following 14 critical words: *drinking, money, apple, pleasant, rest, warm, reading, black, television, foot, desk, buying, hope* and *music*. This is simply because although the word for *reading* may spawn a large list of semantic associatives in Japanese, in English this is not quite as obvious as using the word *read*.

Furthermore, even with the Roediger and McDermott studies, associative norms have usually been taken from collections such as Postman and Keppel (1970) which apart from being out of date have the added drawback for this experiment in that they were collected from American college students during the 1950s and 1960s and are unlikely to be relevant to British English speakers in the twenty first century. For this reason we have chosen to use the Birbeck Word Association Norms by Moss and Older (1996) and pre tested our word lists amongst individuals of the same age group as our participants. Nearly all the critical words have been taken from Roediger and McDermott's original experiment, with the exception of one, galaxy, which replaced girl in the original list in order to avoid duplication of words during the list learning phase. The words are: *anger, black, bread, chair, cold, doctor, foot, fruit, galaxy, high, king, man, mountain, music, needle, river, rough, sleep, slow, soft, spider, sweet, thief* and *window*.

Beeman and Bowdens' coarse and fine coding theory in hemispheric asymmetry

Ito (2001) wanted to examine whether the coarse and fine coding model (Beeman, 1998) of the hemispheres would hold for verbal memory when using the false memory induction paradigm. In 1998 Beeman proposed a model of semantic processing in which the left hemisphere (LH) engages in fine semantic coding, strongly focusing activation on a single interpretation of a word and a few closely related associates, whereas the right hemisphere (RH) engages in coarse semantic coding, weakly activating several meanings and associates (see Figure 1). Another way of describing this is by saying that whereas the right hemisphere sees the woods, the left can discriminate between the individual trees. Furthermore, Beeman et al. (1994) in support of this model found greater priming effects for certain prime types when target words were presented to the left-visual field (lvf)-RH than when presented to the right-visual field (rvf)-LH, in particular the phenomenon was greater when the target word was distantly related to the preceding prime.

Working from this premise Ito (2001) made the following predictions: first, that the hit rate for studied words would be higher when the targets were presented to the (rvf)-LH than the (lvf)-RH since presentation of strongly related targets at encoding should activate the target more strongly in the LH, since this hemisphere encodes in strongly activated but small semantic fields. In our tree analogy the LH will see the tree and remember specifically what type of tree it is. In contrast the RH with its weaker but broader semantic fields will activate all the trees in the forest but with a lesser degree of accuracy in determining which tree was originally presented. With this in mind Ito made a second prediction; false recognition would be high in both hemispheres on presentation of the critical word, but specifically the RH would show higher false recall as unlike the LH it lacks the fine tuning to separate semantically similar items. Ito's (2001) results supported the hypothesis, the RH did indeed show higher levels of false recall, although not as strongly as hoped.

Beeman et al (1994) may provide an answer to Ito's less than robust results. They note: "By definition, the large semantic fields activated by RH coarse semantic coding are only weakly activated, and weak facilitation of the target word might be difficult to detect - just as weak RH semantic processing of single words is difficult to observe" (Beeman et al., 1994, p.29). They went on to point out that in individuals with damage to the right hemisphere "deficits in discourse processing in RHD patients are relatively easy to observe, perhaps because such processing relies heavily on semantic overlap from multiple distantly related words" (Ibid.) This in turn implies that in normal individuals such deficits are much harder to determine. Furthermore, given that during the recall phase subjects only see the words presented to either the (lvf)-RH or (rvf)-LH for 120 ms in order to prevent the eyes moving away from the fixation point, it gives the brain relatively little cognition time to process the semantic relations of one word before moving on to the next. Therefore, this author expects that although the results will show a similar hit and miss rate pattern to that of Ito's, there will be a smaller degree of difference between the hemispheres for false recognition because the critical words will only be presented once either to the (lvf)-RH or (rvf)-LH, in contrast to Ito (2001) who presented each word during the recall phase to both visual fields. We have not chosen this method as there is a risk of each word priming itself across the visual field and thereby artificially elevating the false recall response.

Sex differences

For some time sociolinguists and anthropologists have noted that males and females socially employ language in quite different ways, often as a response to the gender stereotyping and positioning of the societies they belong to (Holmes & Meyerhoff, 2003). Perhaps because of its origins in sociolinguistics sex differences in verbal performance have almost been completely ignored by psycholinguists who often cite the socially gendered aspect of such observations, and inconsistent neurological findings as a reason for this omission (Harley, 2001). However, recent developments in imaging techniques of the brain and new research methods are resulting in mounting evidence for sex differences not only at the structural level, but right down to the cellular level of the brain (Cahill, 2005). Yet the social differences observed between the sexes in language use may have a biological basis according to the sex of the brain. For example, Shaywitz et al., (1995) confirmed the theory that language is less lateralized in female brains and may also be processed differently with female brains showing a far greater degree of activation in the right hemisphere than that of men.

In 1996 Voyer carried out an extensive meta-analysis of research into sex differences. He concluded that "laterality effects are significant and relatively consistent. Specifically, the largest laterality effects are found in verbal tasks in the visual and auditory modality." Since this study is carried out within the visual modality it seems relevant to mention this phenomenon in the present study.

Voyer is careful to note that where laterality is concerned caution needs to be exercised before attempting to use the findings for theory elaboration (Voyer, 1996). However, one explanation for the inconsistency between some of the findings may be that sex differences can be seen as an all-or-nothing scenario. An individual is either male or female, with no possibility of an individual expressing traits of the opposite sex. Yet in the real world this is simply not true on either a biological level (for example, hermaphrodites) or on a social level (not all women are born housewives, not all men want to be merchant bankers). Perhaps a better paradigm would be to view the sex of the brain as falling along a continuum that is not necessarily related to the biological gender of the individual. Some men can exhibit female brain characteristics and vice versa.

One important theory that can aid this paradigm is Baron-Cohen et al.'s (2001) which argues that autism and Asperger's Syndrome (AS) lie on a continuum of social-communication disability, with AS acting as a bridge between normality and autism. Carrying a number of tests using the Baron-Cohen Autism Quotient scale they found significant differences between the sexes. Males scored significantly higher than females, both overall and at intermediate and high levels of autistic traits.

Developing this idea further Baron-Cohen (1999) put forward the hypothesis that autism is an example of the extreme male-brain. This began with his observation that a significantly higher proportion of males than females suffer from either autism or Asperger's Syndrome, a relationship that had previously received little research attention. Baron-Cohen drew on various findings including the fact that in general, females show a faster rate of language development and a lower risk for specific language impairment (Hyde & Linn, 1988; Bishop, 1990). This may be as a result of females having less lateralization in the brain for language compared to males. Baron-Cohen argues that one important assumption of his model is that people fall on a continuum as regards male or female brain types and this can be attributed to the amount of testosterone and androgens a foetus is exposed to at conception through to full gestation in the uterus.

A general area that has been accepted as a sex difference is that of verbal memory recall. Whereas men usually outperform women on visuo-spatial tasks, women outperform men in verbal memory recall and fluency (Kimura, 1992; see also Lewin et al., 2001; Herlitz et al., 1997 and 1999).

How can we apply these ideas to the current work? If female brains are indeed less lateralized then we can hypothesise that there will be a greater degree of false memory when critical words are presented to a female's right hemisphere. The reason for this is that the coarse coding of the right hemisphere in females is likely to be far more active for verbal tasks than in males, so distantly related (but non-studied) words are more likely to be drawn up as targets than in the male brain. Furthermore, we can also hypothesise that the hit rates for studied words will be higher in females than males, given this ability to retain larger semantic fields in the right hemisphere. It may also be that females will be better at males in disregarding non-related distractors. Because the left hemisphere fine coding in both sexes is no different, we will expect the results in this hemisphere for all types of distractor to be equal. If sex differences do not exist then we would expect the false recall rates and correct hit rates for studied words to be equivalent in both males and females.

EXPERIMENT

Methods

Participants. 32 subjects between the ages of 18 and 30 were selected to include 16 females and 16 males. All were native speakers of English and were found to be dominant right-handers using the Edinburgh Handedness Inventory (Oldfield, 1971). All had normal or corrected-to-normal vision. All subjects were paid £6 for participating in the experiment.

Materials and apparatus. Twenty four word lists were used, each consisting of 16 words to include the critical non-studied word and fifteen studied words. For example, for the critical non-studied word *galaxy*, the associated word list were *stars, universe, planet, bar, space, cosmos, infinite, Milky-Way, black hole, nebula, constellation, satellite, moon, sun, asteroid*. The full word list can be found in the appendix. The word lists were selected from the original Roediger and McDermott (1995) experiment, with one exception; *galaxy* replaced *girl* in order to avoid word replication during the recall phase. The word lists were also pre-tested before the experiment among a group of similar aged individuals who did not take part in the experiment. They were also checked against the Moss and Older (1996). Birbeck Word Association Norms.

Design. Visual field and type of distractor word (i.e. studied, critical or non-studied) were the two variables manipulated in the experiment. Both VF (lvf, rvf) and distractor were varied within subject. Gender was included as a between subject variable. Response accuracy was the dependent measure.

Procedure. The experiment fell into two phases. The first was the list learning phase which began with a central fixation cross followed by the word presented horizontally in the centre of the screen. Each word was presented for 1.5 s. In contrast to Ito, who arranged the within-list order according to the strength of association to the critical word, each word list was presented randomly and was counterbalanced across subjects. After the subject had seen all 15 words of a particular list they solved maths problems as a distractor task for 30 seconds before moving on to the next list. This pattern was repeated until each subject had seen all 24 words lists. Again, the order of list presentation was counterbalanced across subjects.

After the final word list had been studied the subjects filled out the Autism Quotient and Edinburgh Handedness scale before moving on to the recall phase. Instructions for the recall phase were presented on the screen with subjects being told to press keys on a response box for yes or no in response to the question, had the word been on any of the original lists? The yes or no keys on the response boxes were also counterbalanced across subjects. The trial began with a central fixation point followed by a word presented either to the left or right of the fixation point, horizontally for a duration of 120 ms to prevent re-fixation. The subject gave their answer via the response box before the next word was presented. The recall phase consisted of 96 items: 48 studied words, 24 unrelated distractors and the 24 critical words. Order of presentation was random and counterbalanced across subjects with each subject seeing 50% of the words to the right visual field, and 50% to the left visual field. The unrelated distractors were selected to be as unassociatively related to the word lists as possible and were pre tested by individuals who did not take part in the experiment.

In contrast to Ito (2001), who presented each word once to the left and then the right visual field, we presented each word only once to either the right or left visual field. It was felt that Ito's (2001) method of presenting each word twice would artificially increase the false response rate of the critical word since each critical word could prime itself across the visual fields. In contrast to Ito (2001), rather than using a chin rest restraint subjects were explicitly instructed to remain as still as possible during the recall phase and remain fixated on the central cross during the trials. They were told to respond as accurately as possible.

Subjects were sat in soundproofed booths in front of Dell Optiplex GX1 machines with Pentium III 733MHz processors and Intel i810e integrated graphics adaptors with 8Meg VRam, displaying at 1024x768 @ 16bit colour @ 60Hz to an Iiyama TXA3823 15" analogue LCD screens. The experiment was run on eStudio software.

Results

We calculated the mean hit rate and false alarm rate for each subject in each condition. As with Ito we presented the hit rates and false alarm rates as a function of the visual field (see Figure 2.). We then analysed these in separate repeated ANOVAs. A one way ANOVA for VF indicated that the hit rate was significantly higher when the words were presented to the (rvf)-LH than when presented to the (lvf)-RH, $F(1,31) = 3.314$, $p < .05$. We then carried out a 2 (VF) x 2 (type of word) ANOVA. A significant main effect for type of distractor was found, $F(1,31) = 174.051$, $p < .001$. The false alarm rate was significantly higher for the critical, non-studied words than for the unrelated non-studied distractors. A significant effect of visual field was also found, $F(1,31) = 4.703$, $p < .04$. As with Ito's work we found that the false alarm rate was significantly higher when words were presented to the (lvf)-RH than in the (rvf)-LH. The VF x type of distractor interaction was not significant, $F(1,31) = .224$, $p > .5$. All these results replicated those of Ito's (2001).

We also ran a repeated ANOVA on the interaction between hemisphere and gender. Gender was not significant overall, $F(2, 31) = 10.941$, $p = .072$. However, separate repeated ANOVAs were run to determine the interaction between gender and type of words. A significant effect of gender was found for correct responses for critical, non-studied words, $F(1,30) = 4.610$, $p < .05$. In general males correctly rejected the critical non-studied words more than females as was suggested by the descriptive statistics (see Figure 3). Furthermore, females had a higher false alarm rate when critical words were presented to the (lvf)-RH (M=73.4%) than when presented to the left (M=62.5%).

Ito (2001) also analysed hemispheric differences by looking at their ability to discriminate between critical words and non-studied words. We repeated this analysis in the same way as Ito by calculating the discrimination scores, that is the correct response minus the incorrect response for critical words and unrelated non-studied words. Furthermore, since we were also interested in sex differences we separated these results for males and females, see Figure 4, in order to see if a further pattern of results emerged related to sex differences.

Unlike Ito (2001) a one way ANOVA did not indicate that the discrimination score was significantly higher when stimuli were presented in the (rvf)-LH than the (lvf)-RH, $F(1,31) = .186$, $p > .5$. This is probably due to a difference in our methodology by only presenting each word once to either the left or right visual field. A between ANOVA analysis indicated that gender was a factor; $F(1,30) = 5.962$, $p <.05$; but was not a significant interaction for the pattern of results found. Although the descriptive results for males was similar to that of Ito's (2001) in that males the LH seemed better able to discriminate between the critical words and non-studied distractors. Furthermore, the descriptive results for the discrimination scores show that females again have a higher false alarm rate in the (lvf)-RH for critical words than compared with males. As a final analysis we also ran a between subject ANOVA to investigate the Autism Quotient scores, but the results were non-significant and as yet no pattern of results has emerged from these findings. Again this may be due to the small number of subjects. However, as predicted the subjects results did fall along a continuum with some male subjects displaying low AQ, usually associated with more female results and vice versa. These results can be found in the Appendix and are discussed below.

Discussion

The results replicated Ito's (2001) work in that we found the correct response rate was significantly higher when words were presented to the (rvf)-LH than to the (lvf)-RH. The false recall rate of the critical non-studied words was also higher than that of the non-related distractors, regardless of which visual field they were presented to. Although we did not find a significant difference in the ability of the LH to more accurately discriminate studied words from critical non-studied words than the RH this result was probably due to our change in Ito's (2001) methodology. Ito presented each word to both visual fields increasing the likelihood of self-priming. Therefore, having once seen the critical word the brain is more likely to reject or accept the word as having been on the original lists according to its order of presentation during the recall phase. This could have a direct bearing on the hemispheres ability to discriminate between critical words and non-related distractors. Furthermore, our use of equal numbers of male and female subjects may have a bearing on these results.

Although we did not find an overall effect of gender there were some significant results with regard to the type of distractor words. In general males correctly rejected the critical non-studied words more than females. Furthermore, females had a higher incorrect response rate when critical words were presented to the (lvf)-RH than when presented to the left. Although this result was not significant, $F(1,31) = 3.974$, $p = .055$, it was borderline to be of interest for our current research considering the correct response rate for gender was significant, $F(1,30) = 4.610$, $p < .05$. Gender was thought not to be significant overall as a result of the lack of degrees of freedom, although this can only be confirmed by repeating the experiment with larger numbers of subjects for both sexes in the future.

The pattern of correct and false response fits well with Beeman's (1998) coarse and fine coding theory. For both males and females the RH falsely recalled the critical word higher than the LH, demonstrating the coarse semantic coding of the right hemisphere; and the LH conversely rejected the critical words more than the RH, demonstrating the fine semantic coding and thereby the more selective nature of the left hemisphere in verbal memory recall. What is of interest is the difference between the two sexes. Why should females falsely recall in the RH more than males? Again the Beeman (1998) model can help us here.

If the female brain is indeed less lateralized than the male with regards to language skills then it would seem appropriate to suggest that in females the right hemisphere is more active during the encoding process compared to males, and thereby creates larger semantic networks or related words. If this is the case then we hypothesised that during the recall phase the right hemisphere in females will show an advantage for correct response to studied words in the RH over the males, which we discovered in our descriptive statistics. For studied words the correct response in the (lvf)-RH for females was M= 75.26%, and for males it was M= 68.49%. However, our hypothesis also argued that a disadvantage would be found in females compared to males when responding to the critical word in the (lvf)-RH. Again we found this in our descriptive statistics where females M=26.04%, and males M=36.98%. This result turned out to be significant, $F(1,30) = 4.610$, $p < .05$. The correct and incorrect response results for the (rvf)-LH in both sexes were almost identical regardless of type of distractor. This suggests that the observed difference in results for the (lvf)-RH is therefore due to a processing difference in the right hemisphere of females compared to males. This would also help explain the results for the discrimination scores. Although the results for males were similar to that of Ito's (2001), in that the left hemisphere could discriminate between critical words and non-studied words better than the right hemisphere, the results for females did not show this discrimination. It could be hypothesised, therefore, that in females the advantage in the RH for correct responses to studied proves a disadvantage for critical and non-studied words. In particular, if the RH in females is more engaged at the onset for encoding words into a far broader semantic network compared to males, it may explain why females falsely recall even the non-studied words as having been on the original lists more frequently than males. It would seem to rule at this anomaly it is very important for the recall phase to include a list of non-studied words that can have absolutely no associative or semantic link to any of the original studied items.

Re-defining 'sex differences': is it really his brain, her brain, or is a better definition male brain, female brain?

Voyer (1996) notes in his meta-analysis that in investigating hemispheric differences between the sexes some studies find differences whilst others do not. Voyer suggests the following:

> "A partial answer to this question may reside in the fact that many studies involve samples of participants that are too small to allow detection of sex differences. One can only wonder why such low sample sizes are used when the effects under study are so small. It is quite likely that, because most researchers are not interested primarily in the detection of sex differences, they use a sample size sufficient for the main effect of laterality to reach significance. Given that the magnitude of laterality effects is much larger than that of sex differences in laterality, this results in studies that are powerful enough to detect laterality effects but not sex differences. From this perspective it might prove useful for future researchers to present power calculations for sex differences in laterality and to include the sample size required for this effect to be significant when it fails to reach conventional significance."
>
> (Voyer, 1996, p.70)

In defence of this current research to Voyer's criticism, we were bound by both time and financial limits, but we do agree with Voyer that far larger subject numbers are required when studying sex differences. Furthermore, as we were attempting to replicate Ito's (2001) work it was felt best at the time to use the same number of subjects as Ito did, since we were primarily interested in whether this paradigm could be replicated. With the best will in the world 16 subjects of each sex was not going to give us enough data points to find significant sex differences. The fact that some were found, however, does indicate that further research needs to be carried out in this area.

If outward gender is not a reliable factor for sex differences we can use the Autism Quotient in future experiments to pre test individuals and categorise them according to their brain sex. But the AQ score alone is not enough. As Baron-Cohen et al. (2001) note, "The AQ is thus a valuable instrument for rapidly quantifying where any given individual is situated on the continuum from autism to normality", but it is not reliable at this stage to situate an individual's brain on the continuum from male to female.

Another scale that could be used comes from Manning's work on 2nd and 4th finger ratio. The ratio between these two fingers has long been accepted as a sexually dimorphic trait. In general, the mean 2D:4D ratio in men is lower than that in women (Phelps, 1952). This anomaly was in later years found to be under the control of the Homeobox, or Hox genes, which also control the differentiation of testes and ovaries during development of the foetus (Peichel et al., 1997; Herault et al., 1997). Manning et al. (1998) took this idea one step further and suggested that patterns of 2D:4D ratios may reflect aspects of gonadal function such as the production of testosterone and oestrogen.

During development, the human foetus is exposed testosterone and oestrogen at different stages during its development. Obviously, high testosterone will favour a male foetus, and high oestrogen the female foetus (Manning et al., 2000). Manning et al. (2000) argued that the 2nd to 4th finger ratio is also a marker for sexually antagonistic genes that exert their effects prenatally:

> "On the one hand, low 2D:4D may indicate prenatal exposure to high testosterone and low estrogen levels, a situation that enhances fertility in males but reduces it in females. On the other hand, high 2D:4D ratios may correlate prenatally with low testosterone and high estrogen and be associated with low fertility in males and high in females."
> (Manning et al., 2000, pp.164-165)

But how would this influence the development of the brain?

> "The prenatal period, particularly, the first trimester of pregnancy, is very important for the organization of the central nervous system, urinogenital system, and cardiovascular system. Prenatal testosterone and estrogen have their impact on differentiation when systems show sex-limited differences. Therefore, it is likely that 2D:4D will prove to be a marker for many traits that show sex limited expression. These may include behavioral traits such as handedness, verbal fluency, spatial judgment, autism, schizophrenia, and depression."
> (Ibid, p.181)

One such area is language, so we could hypothesise that if the brain during foetal development is also influenced by these hormone fluctuations, regardless of the biological sex of the individual, the brain sex will be also reflected in 2D:4D ratio, and like the Autism Quotient it also reflects the nature of brain sex to fall along a continuum.

Conclusion

The main outcome of our work was that we managed to replicate Ito's (2001) results, although not the discrimination scores. However, since we altered the methodology this may have influenced this particular result. Furthermore, as laterality effects can be quite small and hard to investigate it may be, as with investigating sex differences, that our results simply are a reflection of too small a population sample. In addition to this as sex differences may have an influence on the outcome of false memory recall, since we used an even ratio of male to female subjects whereas Ito (2001) had only 4 males out of 32 subjects, this may also have been a factor in our failure to find signifcant discrimination scores.

Although sex diffferences were not significant overall some aspects of type of distractor were found to be significant, in particular the result of females falsely recalling the critical word more than males. Again, Voyer's (1996) criticism of research into sex differences needs to be accommodated with again attention being paid the number of particiapnts used. Furthermore as Beeman et al. (1994) noted since weak right hemisphere semantic processing of single words is difficult to observe when we add this to teh factor of sex differeces being difficuly to observe along with laterality effects it becomes even more surprsiign that any results of significance were found, and proides a good testimony for teh Robustness of Beeman's (1998) coarse and fine coding model as well as Ito's (2001) experimental paradigm for investigating hemispheric asymmetry.

Such findings could play an important role in how we model language performance. Traditionally, psycholinguists have preferred to fit one model to both sexes, but if language function is different between the sexes than this one-model-fits-all approach may not always be appropriate, particularly in experiments which rely on any form of verbal memory recall, such as investigating garden-path sentences or anaphora resolution (Harley, 2001). It may be that the sometimes conflicting results observed by psycholinguists in these experiments is a factor of sex distribution in subjects rather than a factor of experimental procedure per se.

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